AUTEX 2022 Conference Proceedings 978-83-66741-75-1

DOI: 10.34658/9788366741751.8

CUT PROTECTIVE MATERIALS FROM THE POINT OF VIEW OF WORKING ENVIRONMENT

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ABSTRACT

Cut resistance is defined as the ability of material to resist a blade, which may be determined by means of a variety and evaluation methods, depending on the intended use of the material and the applied cutting factor. Some of the earliest studies on cutting were conducted in the 1990s involving textile and polymeric materials. The obtained results were characterized by exponential regression indicating that blade movement (the length of the cutting path) decreases with increasing loading. Those results were reflected in the first version of the international standards specifying cut resistance testing [1–2].

Cut resistance tests given in international standards are mostly used for proving that products meet specific normative requirements, but they fail to account for the complexity of the physics of cutting and fall short in terms of evaluating advanced materials arising with the fast-paced development of materials technologies [3]. Moreover, the available literature does not contain many research on the cut resistance properties of e.g. three-dimensional hybrid textile materials taking into account the real conditions of use. As a result, it is need to develop more objective methods for evaluating cut resistance properties, therefore preliminary assumptions for the new method has been described in this paper.

KEYWORDS

Cut resistance, protective gloves, non-standard test methods.

MATERIALS AND METHODS

Characteristics of the tested knitted fabrics (S.I. ZGODA, Poland) are presented in Table 1. Cut resistance of textile materials were assessed using two standard methods [1,2]. The test methods described in those standards differ in type of blade, EN 388:2016+A1:2018 employs a round cutting blade applying constant cutting force, while EN ISO 13997:1999 uses a straight blade applying variable cutting force.

Table 1. Characteristics of tested materials.

Sample identification	Type of structure fabric	Type of yarn	Surface mass, g/m^2	Thickness, mm	Tightness
DR-1.1	knitted	polyester, glass	490.9	1.20	94/10
DR-1.2	knitted	polyester, glass	412.1	1.26	104/10
DR-2.1	knitted	polyethylene, glass	316.3	1.06	88/10
DR-2.2	knitted	polyethylene, glass	348.2	1.08	100/10

First cut resistance test method (using circular blade) was determined on the basis of index ‘I’, which is an abstract number calculated as an arithmetic mean of five ‘i’ indexes calculated on the basis of the number of blade rotations causing the cutting of the test sample and control specimen. The blade used for the test is a discs with a diameter of 45 ± 0.5 mm, thickness of 3 ± 0.3 mm and with a total cutting angle of 30–35°. The blade loading amounts to 5 ± 0.05 N, whose sharpness is checked before each test performed on the material sample with a control specimen.

Second cut resistance test method (using longitudinal blade) was determined on the basis of various values of force exerted on the blade. Data obtained from tests with at least three different forces (for each force value five cuts of a test sample are carried out) are used for plotting a graph of the correlation between the cutting distance and values of forces applied. From this graph the force needed to cut through the test sample with a 20 mm blade displacement is determined.

RESULTS AND DISCUSSION

Test results are presented in the Figure 1. Tests were carried out for the same samples, first using rotating circular blade and then using . The next stage was a comparison of results obtained in the tests according to both standards.

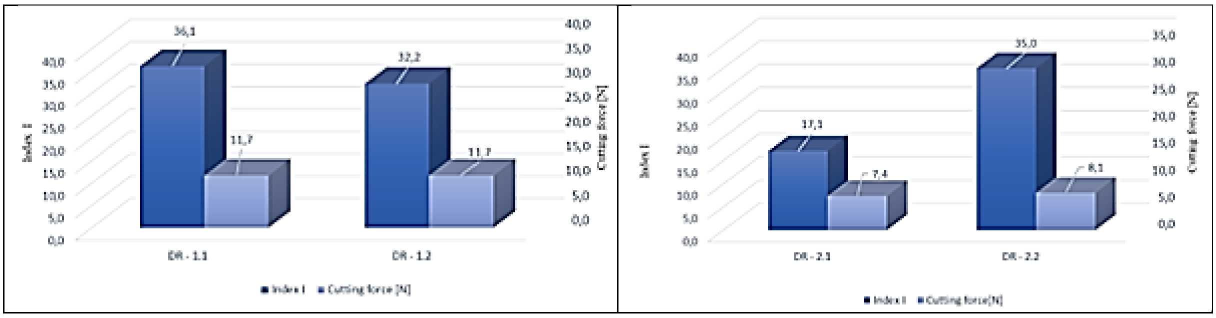

Figure 1. Cut resistance test results.

The highest cut resistance according to EN 388:2016+A1:2018 was obtained by knitting polyester and glass fibre (DR-1.1) while cut resistance according to EN ISO 13997:1999 was relatively low. Tests on different types of material indicated that in some cases this test method seems to be insufficient for evaluation of glove resistance to cutting, concerning gloves made from textile fabrics highly resistant to cutting. Because of significant blunting of the blade occurred during the test it could be failed to determine the real cut performance level according to EN 388:2016+A1:2018. On this basis test results could show a high resistance to cutting, while the material does not provide high cut protection.The case of that sample confirms in particular that the method which is using circular blade is not reliable for tests performed on materials with very high resistance to cutting. Rapid blunting of the cutting edges of blades and consequently the impossibility of providing reproducible conditions for the experiment poses a key problem during cut resistant evaluation [4].

It was found that using the longitudinal blade allows to conduct the test and determine more real values of resistance to cutting. The blade is used only one time for one cut and degradation of the blade is not observed during the test, which allows to ensure more uniform conditions during the test. On this basis, it was considered that it also is needed to effort underway to develop objective test methods for evaluating cut resistance properties, which approximates the real conditions of use. Assumptions for a method simulating more real exposure conditions are shown in Figure 2.

As a result, efforts are underway to develop more objective test methods for evaluating cut resistance properties because the standard method takes into account only blade angle of 90°, and it is important to take into consideration other blade angles as well, as may occur in the working environment.

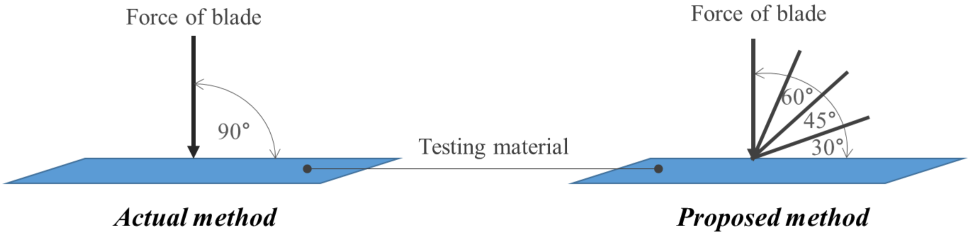

Figure 2. Assumptions to determination of cut resistance using variable blade angle.

One of the latest examples is the study by Messiry et. al., [5], which describes a novel device for the cut-resistance testing of textile materials. The device can be adjusted in terms of cutting rate and angle. The rotational speed of the blade can be varied between 0 and 1500 mm/s, and the cutting angle between 0 and 80°. The possibility to modify several factors affecting the cutting process during a test is a novel approach coming closer to the simulation of actual, real-life cutting conditions. The authors also noted that during actual testing outside a laboratory setting, textile materials are subject to a number of factors, such as stress, bending, and shear forces, which are by nature dynamic. Investigations involving cotton fabrics showed that cutting angle has a significant effect on the maximum cutting force and energy, because they rapidly decrease upon changing the angle from 0° to 30°. It was found that the cutting rate also influences the maximum cutting force.

Nevertheless, those studies concern only the process of cutting flat textile materials. Therefore presented preliminary research is being carried out to test cut resistance properties using variable loads applied to the blade and different angles from 15° to 90° and using blades of varying thicknesses including evaluation of cut resistance properties of advanced materials taking into consideration three-dimensional hybrid textile materials. The cutting process consists of normal and sliding movements; the process itself is controlled by the friction forces between the blade and the material being cut. As a result the total energy required to propagate a cut strongly related to the fiction coefficient occurring between the face of the blade and the material. However, it should be noted that the friction coefficient is determined not only by the type of blade, but also by the type of material being cut, and especially by the roughness of its surface [6]. Thus, it is of particular significance to describe the process of cutting hybrid materials, combining elements with different properties, and especially textile materials combined with polymeric ones. An important research area is evaluation of the surfaces of functionalized fabrics, which makes it possible not only to assess their properties but also use the obtained data in the modeling of these processes. Physics of cutting textile fabrics differs from that of polymeric materials. In the case of polymer-coated fabrics we have to do with two types of friction forces, that is, macroscopic friction resulting from the applied normal force on both sides of the blade and sliding friction associated with the cutting of the material, which occurs along the tip of the blade. For textile materials, the applied force is cumulated at the tip of the blade, while the friction resulting from the pressure of the fabric on both sides of the blade is close to zero [7–9]. On the other hand, the process of blade penetration into an elastomeric coating involves two constituent forces: pressure force and shear force. The response of the material to those forces is determined by its elasticity and friction between the material and the blade [10].

Aliverdipour et al. [9] showed that blade geometry has a major effect on penetration parameters, as well as the shape and extent of damage to the material. Their results indicate that the higher the angle of the blade tip the higher the force necessary to damage the fabric. This emphasizes the importance of in-depth analysis of the geometry of material surfaces in connection with blade geometry, to determine their influence on the cutting of hybrid cut-resistant materials.

Wang et al. [11] described the factors affecting the mechanical model of cutting; they include the actual contact area between the blade and the material, the plastic deformation of the material under the influence of the cutting force, and the mechanical behavior of the material when a loading is applied (e.g., tribological properties that material surface and tear strength).

Published results indicate that resistance properties largely depend on friction between the blade and the material. The total energy necessary to cut through a material consists of two components: the loss of energy dissipated by the force compressing the sides of the blade (exerted by the material being cut) and the cutting energy of the tip of the blade [12].

Given the above, it is of the essence to investigate the process of cutting through hybrid materials, combining textile fabrics and polymers under variable cutting conditions.

CONCLUSION

It is important to develop testing methods that reflect working conditions because the standard methods are limited and it is necessary to extend the methods for assessing anti-cut properties of textile materials. Gloves made of high-strength yarns effectively protect workers during operations involving contact with sharp tools as well as materials being processed, such as metal sheets or glass panels.

It is very important that workers should use only those gloves with confirmed protective properties tested. For this reason, this paper presents preliminary assumptions to enable the determination of cut resistance using variable blade angle as it is important from the point of view of applications in the working environment to take it into consideration.

ACKNOWLEDGMENT

This research was funded in whole or in part by National Science Centre, Poland, Grant number 2021/41/N/ST8/04281. For the purpose of Open Access, the author has applied a CC-BY public copyright license to any Author Accepted Manuscript (AAM) version arising from this submission.

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